Localized Imaging, Surveying and Mapping for Nuclearized Underwater Robots

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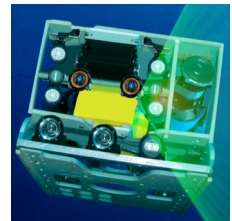Richard Minichan – Savannah River National Laboratory

ABSTRACT:
This initiative will develop, demonstrate and infuse a leap of sensing, robotics, spatial positioning and visualization capability into underwater nuclear operations relevant to DOE EM. The program will develop and demonstrate a prototype robotic system to maneuver in a water-filled basin, obtain high-resolution color video, perform SLAM localization and mapping, map radiation, NDE basin structure, and integrate/correlate this data for analysis, visualization and computer simulation.   There will be a strong thread of research, education, promulgation and transfer. The program will deliver benefits of efficiency, economy, consistency, quality and safety. Results will be applicable to the perennial evaluations of structural integrity, material inventory, repackaging and continuous agenda of fuel management workflow.

The project will localize tools, sensors and robots without navigation drift. The technology will build consistent 3D models of operational surroundings and integrate additional measurements such as NDE and radiation data to support visualization, analysis and simulation. We will develop a scalable sensor module that can be added in varying configurations to existing tools, ROVs. We will develop a specific, fully-integrated work system and demonstrate that in this program. The baseline sensor module incorporates visual, inertial, and pressure sensors to support simultaneous localization and mapping (SLAM).   Radiation, NDE, and a new Episcan sensor are attachable for inspection. The Episcan is a research effort that, if successful, would generate a leap of unprecedented local, 3D hi-res, hi-accuracy models that are beyond possibility of traditional stereo or lidar. This could be a breakthrough of far-reaching value for DOE EM.

Figure 1: Sensor module

We will build on our extensive prior work on SLAM, state estimation, dense 3D modeling and drift-free navigation for underwater robots. We will leverage our deep technical legacy from scientific, defense and commercial experience with a program of targeted research and systems development. The project will address robustness of the SLAM solution to sensor, electronic and camera faults as might be caused by radiation. The project will further include innovative work on underwater structured light sensors, building on our recent development that is suitable for operation in poor visibility.

Initial sensing and SLAM experiments will precisely position and move sensors in a laboratory water tank by deployment from a robotic manipulator.   This provides the absolute positioning, repeatability and full coverage of locations and orientations in an underwater world to develop, calibrate and exhibit the

technical developments. An early sensor module will gather data and be evaluated by stick-deployment in the L-basin at SRNL, where it will remain for repeated testing. A later sensor module will be combined with a GE-provided robot platform to test in a mockup reactor setting in San Jose, CA and possibly in a commercial nuclear reactor. Concurrently, the program will relate to DOE need, identify end-use ambitions, develop requirements and undertake a collaborative system development that is specialized for site demonstration.

The physical underwater robot solution developed in this proposal will go beyond generic capability to move, sense and self-locate. Through alliance with SRNL the work will identify, address, co-develop and co-demonstrate a system relevant to infusion and end use. Candidates include structural survey, automation of inventory, or some element of "can-in-can" inspection.

As example, the technology will be a leap of capability for Basin surveys and evaluations. DOE Basins will continue to be surveyed in perpetuity for damage, cracks, algae accumulations, anomalies, radiation and unanticipated eventualities. Capabilities will go far beyond the current practice of manual camera deployment and fly-by video. Rather than displace human methodology, the technology will augment by generating quantitative, basin-registered models as basis for scientific visualization and year-over-year comparison over time. Fly-by video is vulnerable to vagaries of viewpoints, zoom, lack of position reference, imperfect coverage, lack of scale, lack of consistently high resolution. The proposed technologies will generate fused, full-coverage, models for analysis, trending and scientific interpretation. The spatial modeling and position estimation of the proposed research will be invaluable for situational awareness, proximity with contact safeguard, registration of data-to-world, tool-to-work, surface-following and for the planning, tracking, control and recording of operations. When combined with the UT, NDE and sensing of this proposal, data will be registered to the coordinates of the pool and registered to its contents.

Beyond DOE, the impact to commercial underwater nuclear operations will be substantial, since results will be infused by and with GE, cross-pollinated with DOD and industry, and promulgated in the literature.

The team consists of CMU, UMich, GE and SRNL. The universities bring distinguished robotics, underwater SLAM, systems, field demonstration, infusion and leadership experience. CMU has a deep record of applied nuclear operation developments, experiments and operational campaigns. SRNL brings a deep record of applied remote systems, development of most existing basin tools, and site purview over the L-Basin as a primary demonstration venue. GE is a world leader in underwater nuclear platforms, NDE, technology, fuel pool servicing and commercialization.

Figure 2: 3D, scene-registered scientific visualizations generated by robotics, sensing and SLAM will transform underwater DOE EM operations, inspections, structural evaluations and work flow. Component capabilities can be widely applied beyond specifics of this program's physical form and demonstrations. The proposed work will test with existing and developmental robot platforms.